

The background of the slide features a composite image of Mars, Earth, and the Moon against a black sky. Mars is on the left, showing its reddish-orange surface and polar ice caps. Earth is on the right, showing blue oceans, white clouds, and brown landmasses. The Moon is in the upper right, showing its cratered surface.

# Mars Exploration

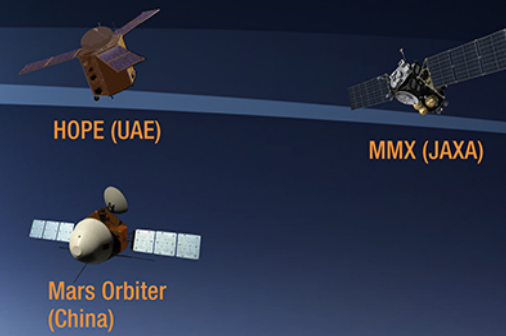
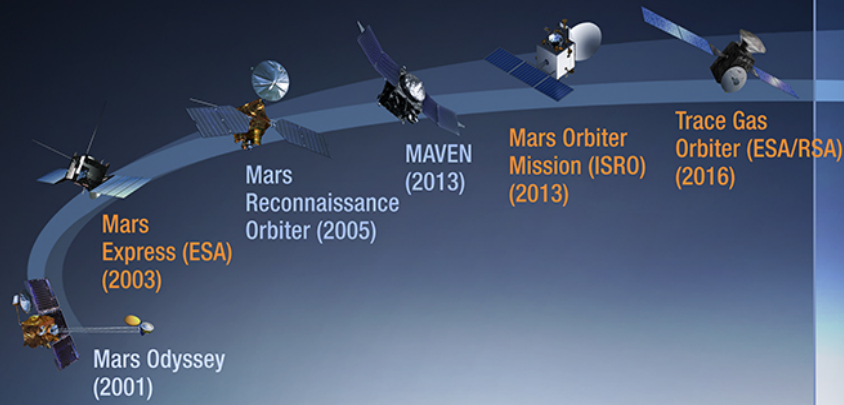
**Roger Gibbs**

Mars Exploration Program  
Jet Propulsion Laboratory  
California Institute of Technology

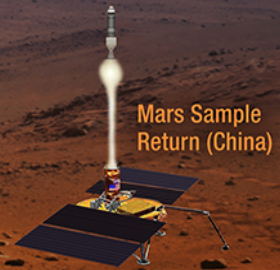
# MARS MISSIONS

OPERATIONAL 2001–2017

FUTURE 2018–2030



Planning MSR



Follow the Water

Explore Habitability

Seek Signs of Life

Prepare for Future Human Explorers



# Overview of Mars Exploration

## Scientific Findings:

- Mars was once habitable—was it ever inhabited?
- Water flowed on and beneath the Mars surface intermittently over the first half of the planet's history.
- Mars has lost  $\geq 70\%$  of its ancient atmosphere and most of its water.
- Mars has resources: Ice, hydrated minerals,  $\text{CO}_2$ .

## Engineering:

- Improved delivery systems bring heavier spacecraft more precisely to the surface.
- Surface mobility brings access to a diverse environment.
- Autonomy (e.g., visual odometry) increases safe driving range.

## Operations:

- Orbital relay infrastructure enhances data return from surface assets.
- Long duration missions enhance overall mission return.
- Complex operations (e.g., drilled samples analyzed onboard) have been conducted.

# Evolving Rover Capability

10.5 kg → 174 kg → 900 kg

Spirit/Opportunity  
(2004)

Curiosity (2011)

Pathfinder /  
Sojourner (1997)



# Pathfinder Sojourner: First Rover on Mars

Landed July 4, 1997

Ares Vallis, Mars

- An ancient flood channel

Solar powered vehicle

Communicated with Earth  
thru Lander

Alpha Proton X-Ray Spectrometer



# MER – 2<sup>nd</sup> Generation Mars Rover

## Spirit and Opportunity

### BY THE NUMBERS

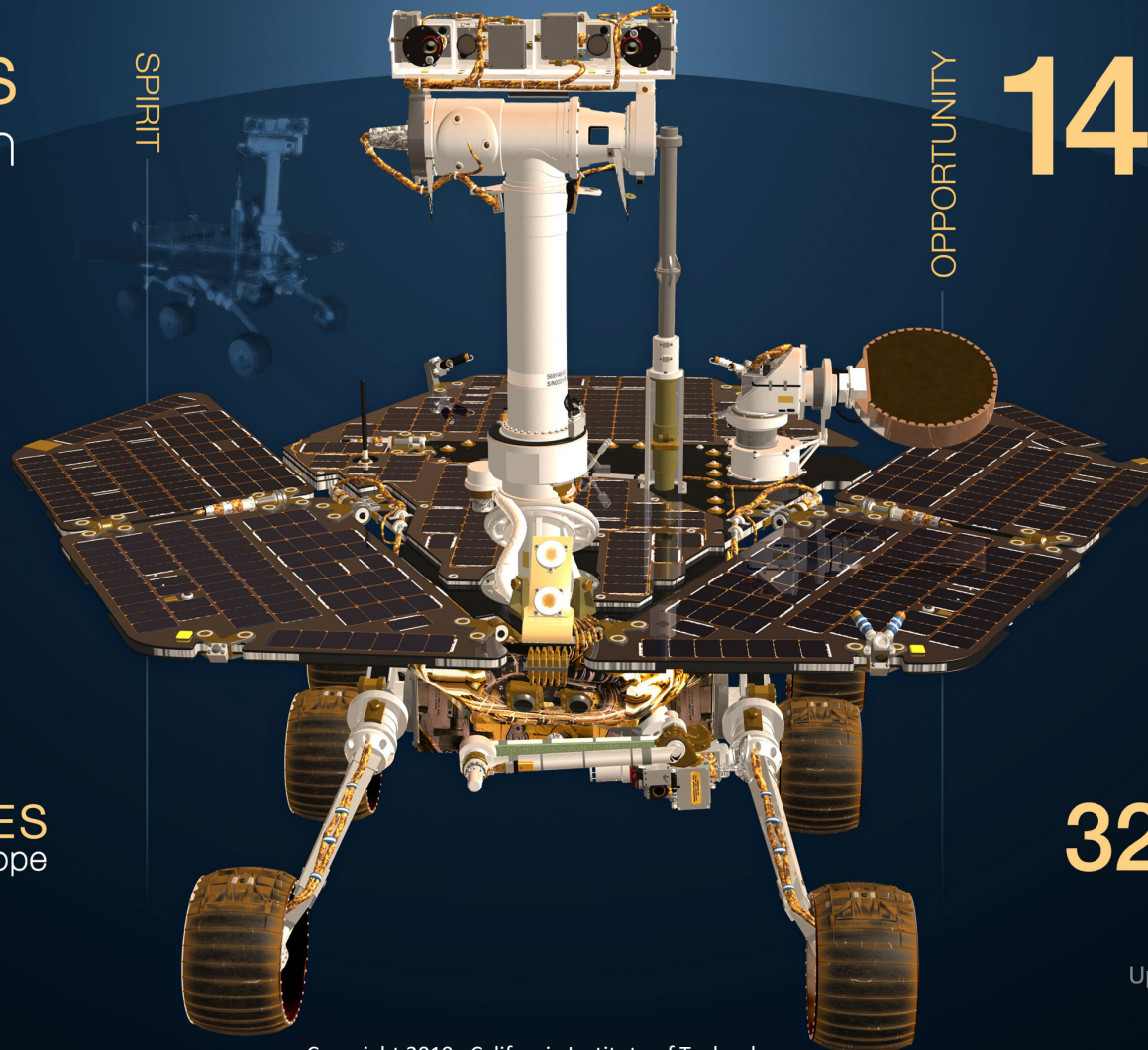
**6 YEARS**  
lifespan

**124,838**  
raw images

**4.8** MILES  
traveled

**30 DEGREES**  
steepest slope

SPIRIT



OPPORTUNITY

**14+ YEARS**  
lifespan

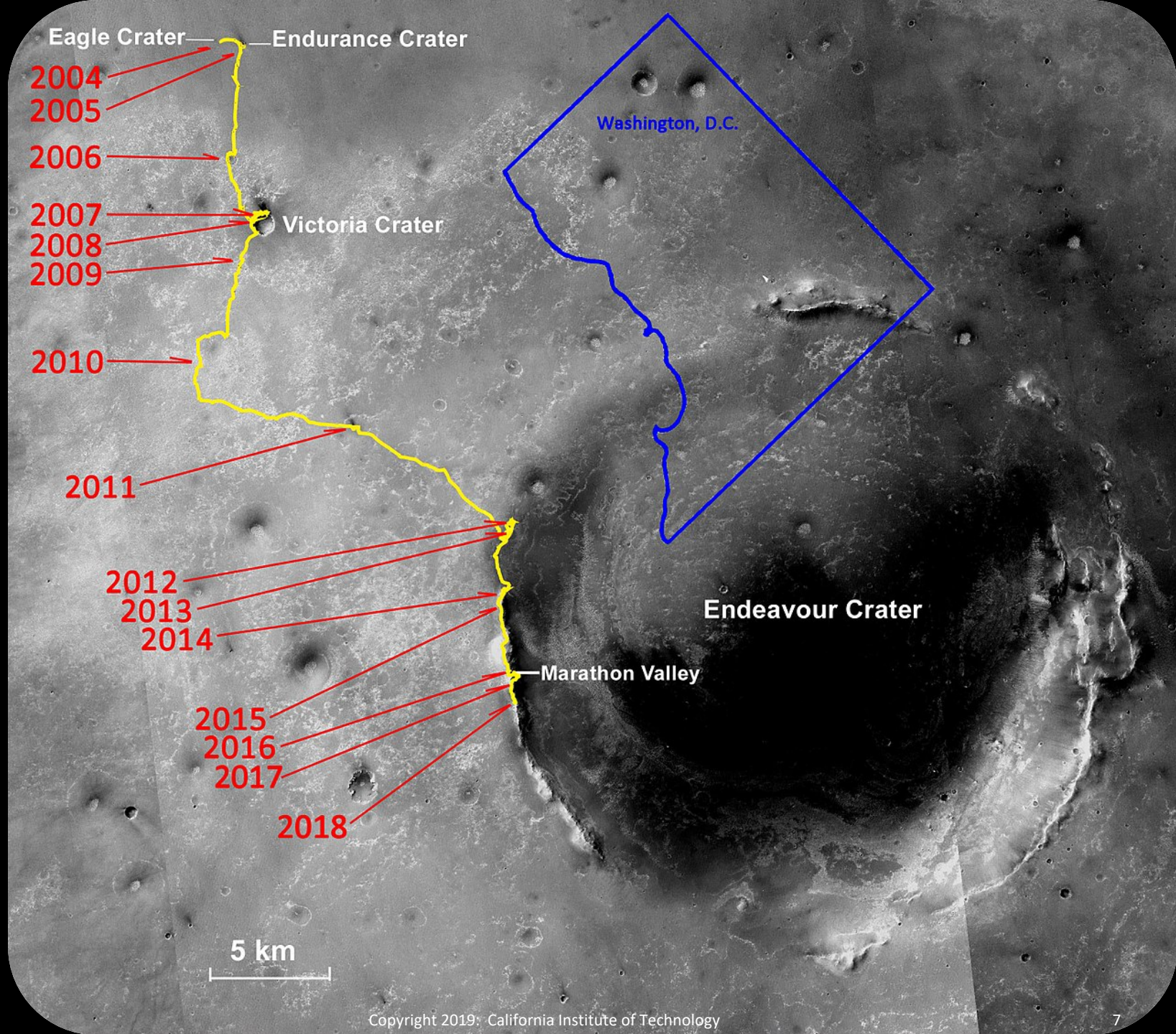
**217,594**  
raw images

**28** MILES  
traveled

**32 DEGREES**  
steepest slope

Updated February 4, 2019

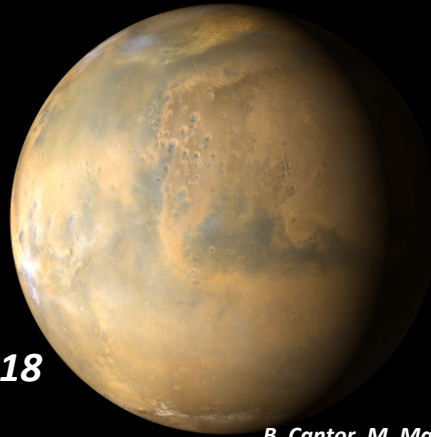




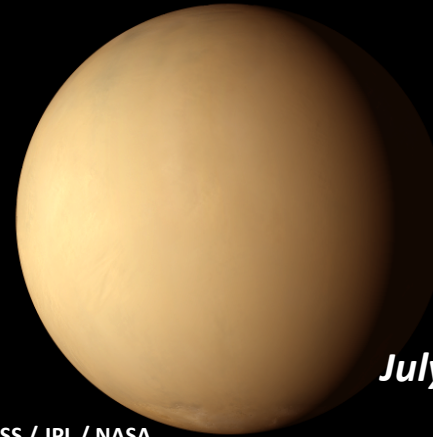
# The 2018 Planet Encircling Dust Event

MRO MARCI

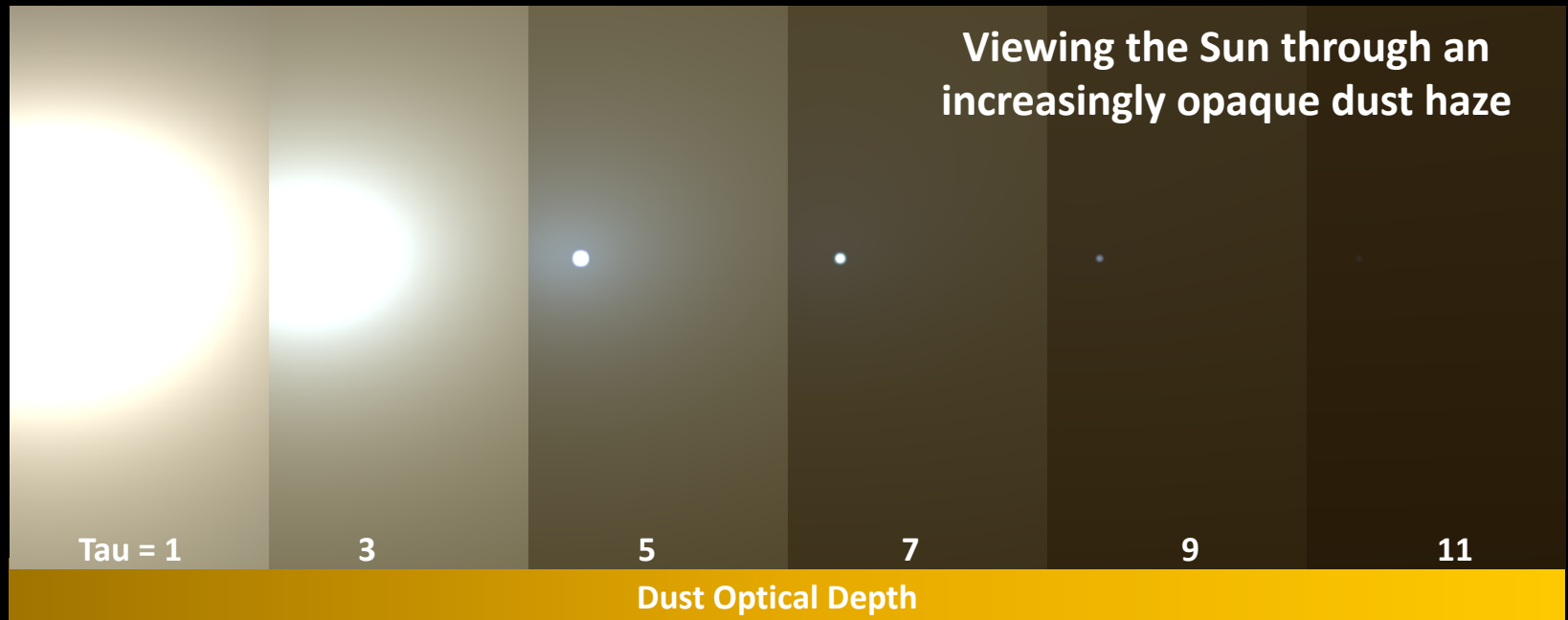
*May 28, 2018*



*B. Cantor, M. Malin MSSS / JPL / NASA*



*July 1, 2018*





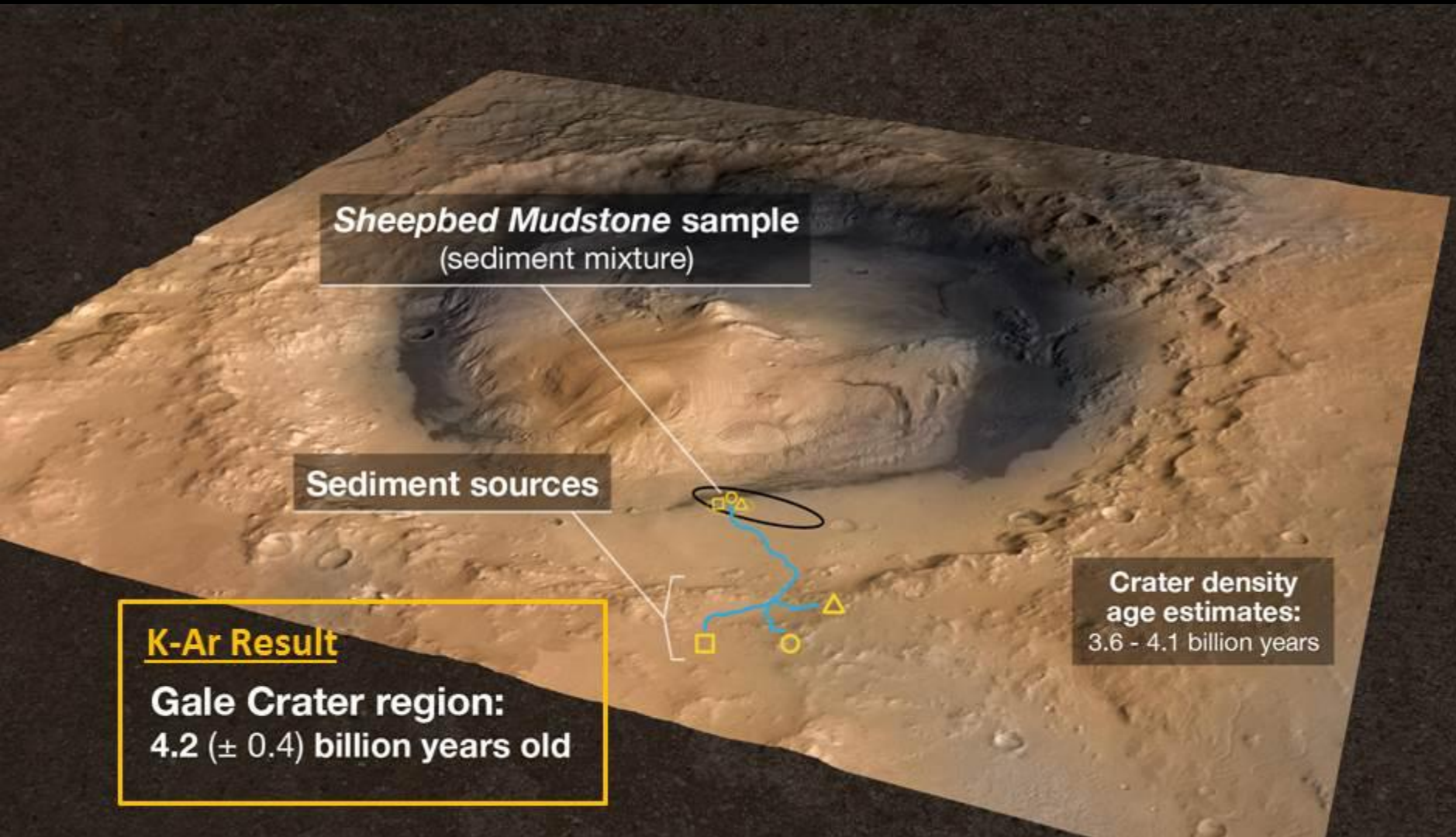
# Curiosity – 3<sup>rd</sup> Generation Mars Rover

“Skycrane” design –  
increased mass  
delivery, lands on  
wheels, descent  
engines far from  
surface



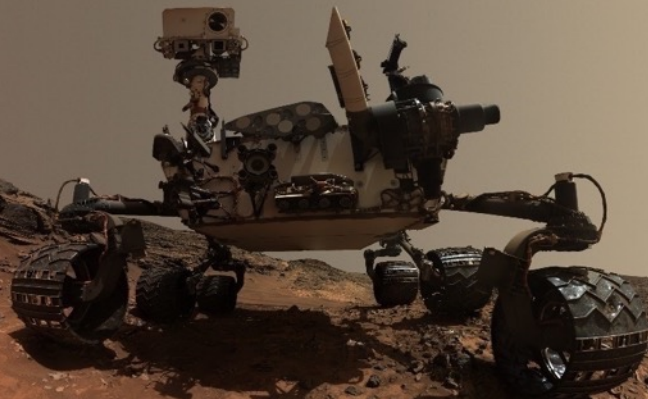
Landing accuracy –  
within 10 km; strong  
feedforward to Mars  
Sample Return, Human  
Exploration

# Curiosity Lands at Gale Crater





# *Curiosity* at Vera Rubin Ridge





# Mars 2020 – Gathering Samples for Possible Return

## SEEKING SIGNS OF PAST LIFE

### CONDUCT RIGOROUS IN-SITU SCIENCE

GEOLOGICALLY DIVERSE SITE

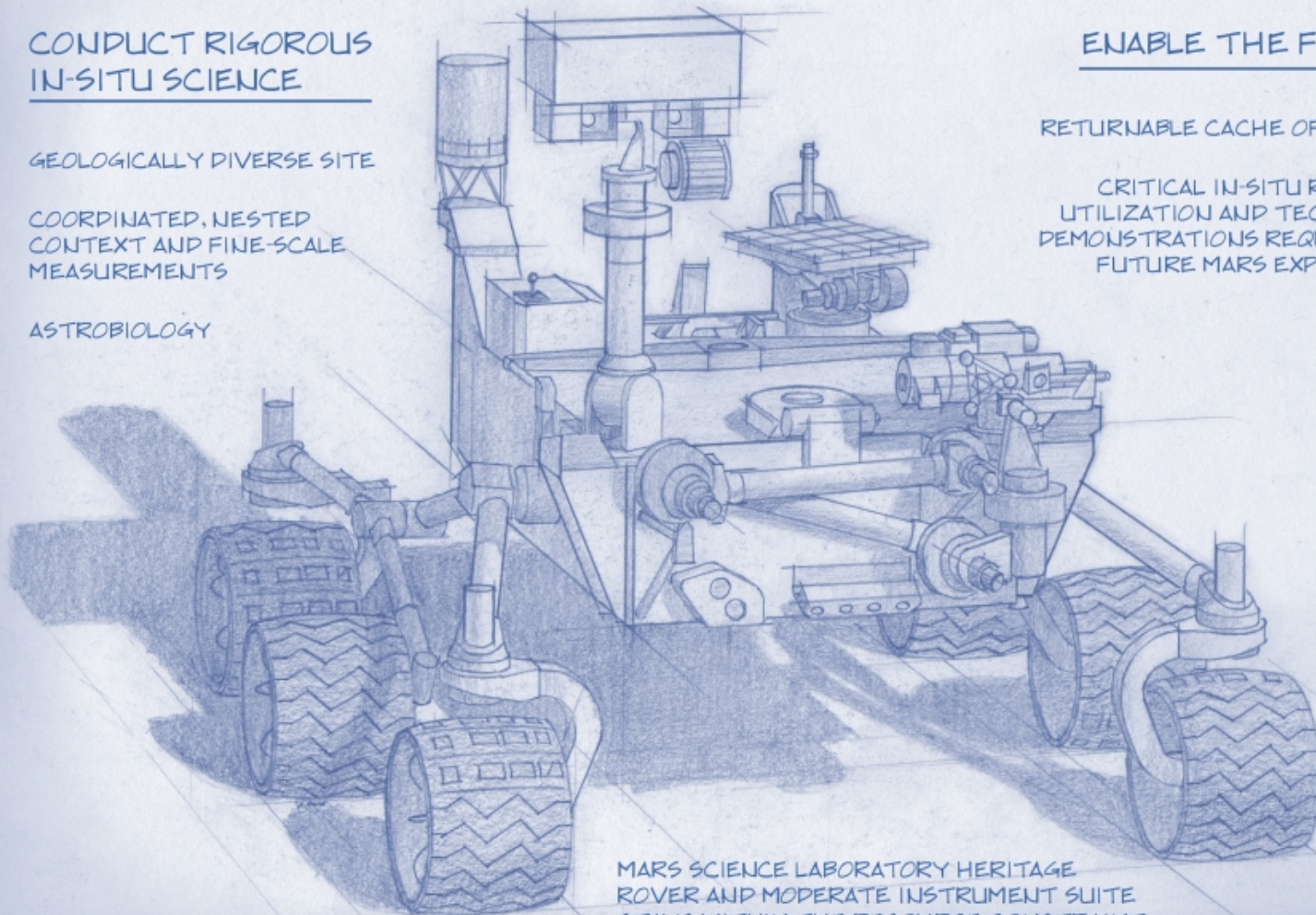
COORDINATED, NESTED  
CONTEXT AND FINE-SCALE  
MEASUREMENTS

ASTROBIOLOGY

### ENABLE THE FUTURE

RETURNABLE CACHE OF SAMPLES

CRITICAL IN-SITU RESOURCE  
UTILIZATION AND TECHNOLOGY  
DEMONSTRATIONS REQUIRED FOR  
FUTURE MARS EXPLORATION

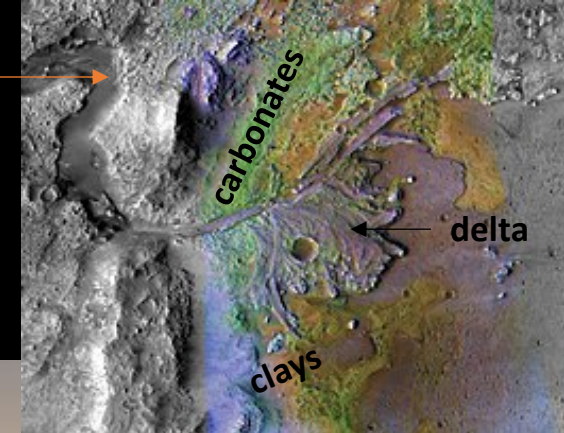


MARS SCIENCE LABORATORY HERITAGE  
ROVER AND MODERATE INSTRUMENT SUITE  
STAYS WITHIN THE RESOURCE CONSTRAINT



# M2020 landing in Jezero Crater in 2021

Mars 2020 will carry ~40 total sample tubes with ~20 to be filled in a 1-Mars year primary mission

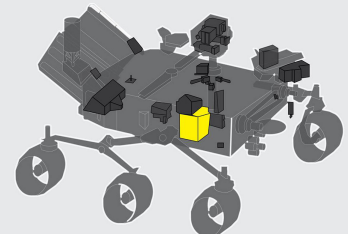


Mineralogy from MRO CRISM  
NASA / JPL / JHUAPL / MSSS / Brown U.

Sample  
Return  
Tube



**MOXIE: Mars  
Oxygen In-Situ  
Utilization  
Experiment**



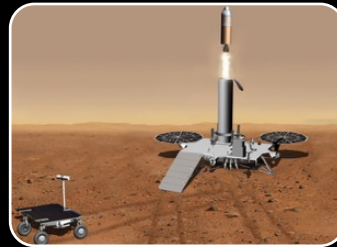
Artist's Conception: M2020 on the Floor of Jezero Crater

# Notional Mars Sample Return Architecture

- “Focused” Sample Return: Three flight elements plus one ground element
  - Capitalize on existing assets and past experience
  - **Focused scope** on 2011 Decadal Survey top flagship priority
    - Payloads focused on MSR objectives; may be secondary launch opportunities
  - Build on technology investments (e.g., Mars Ascent Vehicle)
  - Leverage partnerships (e.g., the recent NASA-ESA Statement of Intent on MSR)



**Sample Caching  
Rover**  
(Mars 2020)  
*Sample  
acquisition and  
caching*



**Sample Retrieval  
Lander**  
*Fetch Rover  
Orbiting Sample  
container (OS)  
Mars Ascent  
Vehicle*



**Earth Return  
Orbiter**  
*Rendezvous and  
On-Orbit Capture  
System  
Earth Entry  
Vehicle*



**Mars Returned  
Sample Handling**

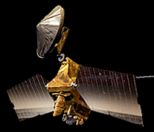
- *Sample Receiving  
Facility*
- *Curation*
- *Sample science  
investigations*

**Flight Elements**

**Ground Element**



# Looking Ahead



- Continue the ongoing scientific exploration of Mars while preserving the infrastructure needed to support future missions

- Get Mars 2020 launched and safely operating on Mars
- Support the next steps in the potential Mars Sample Return campaign
- Provide information for the design and operations of future missions supporting exploration by humans *on* Mars

